Estimation of Human Error using Fuzzy Relation

L. Swaanika, R. Sujatha, D. Nagarajan

***Abstract:** The estimation of human error is a contributory factor for many industrial and nuclear accident occurrences. Organizational factors, situational factors and individual factors are performance influencing factors causing human error. Training quality is organizational factor whereas attention and skill experience are individual factors. Training quality is considered at three levels namely, low, moderate and high. Occurrence of human error depends on training quality, attention and skill experience. These being cognitive in nature, uncertainty are prevalent. Fuzzy relational theory is suitable to capture these uncertainties. This paper deals with the application of fuzzy relation between training quality, skill experience and human error. The proposed approach gives an insight on training quality and skill experience based on which suitable corrective measure can be adopted to decrease human error.*

***Index Terms:** Fuzzy relation, Human error probability, Human reliability analysis, Membership function.*

I. INTRODUCTION

In nuclear and process industries, incorrect human action is a significant factor for occurrence of accidents. Human error is deviation between the actualised action and intended action. The probability that the job or task will be done successfully by the individual at any specified stage in system operation with minimum time is defined as human reliability [1, 2, 3]. Human reliability analysis (HRA) in various fields is discussed in nuclear power plants and safety systems [4], marine [5, 6], medical [7], transport and railway systems [8], aircraft maintenance [9], oil and gas refinery [10] and many other industries [11].

Various aspects of HRA is presented in [12]. The strength and weaknesses of methods such as THERP, A Technique for Human Event Analysis (ATHEANA), CREAM, Standardized Plant Analysis Risk Human Reliability Assessment (SPAR-H) and Success Likelihood Index Method using Multi-Attribute Utility Decomposition (SLIM-MAUD) is dealt in [13]. Life time of system is estimated using fuzzy concepts [14, 15, 16]. Fuzzy approach for fault tree analysis to calculate reliability is discussed in [17]. Basic concepts of fuzzy sets are presented in [18, 19].

A fuzzy relation R is a membership function defined on any two fuzzy sets A and B over the Cartesian space $X \times Y$ given by $\mu_R(x,y): A \times B \to [0,1]$ defined by

$$R = \{((x,y), \mu_R(x,y)) \mid \mu_R(x,y) \geq 0,\ x \in A,\ y \in B\}.$$

Here, the fuzzy relation R is an ordered pair of elements (x,y) representing the fuzzy sets A and B respectively. Similarly, the fuzzy relation of union, intersection and complement over any two fuzzy relations R and S is given by

$$\mu_{R \cup S} = \max\{\mu_R(x),\ \mu_S(x)\} = \mu_R(x) \vee \mu_S(x)$$
$$\mu_{R \cap S} = \min\{\mu_R(x),\ \mu_S(x)\} = \mu_R(x) \wedge \mu_S(x)$$
$$\mu_{\bar{R}}(x) = 1 - \mu_R(x)$$

Generally, the fuzzy relation can be assumed to be a fuzzy restriction to the Cartesian product $X \times Y$. Therefore, the fuzzy relation $R \subseteq X \times Y$.

Let R and S be any two fuzzy relations of an ordered pairs (x,y) and (y,z) over the fuzzy sets A and B, B and C respectively. Then, the grade of membership for the fuzzy relation $\mu_R(x,y)$ and $\mu_S(y,z)$ forms a composition T from the fuzzy sets A and C as $T = R \circ S$

$$\mu_T(x,z) = \bigvee_{y \in B} (\mu_R(x,y) \wedge \mu_S(y,z))$$

In this work, we consider performance shaping factors for human error estimation in a power grid system using max-min composition fuzzy relation.

II. PROPOSED APPROACH

The present study deals with applying fuzzy relation to address the uncertainties between the PIFs. The selection of PIFs is important. The PIFs which cause major impact should be considered. Further, they should be independent as much as possible; measurable. The schematic diagram is presented of the proposed approach is given in Fig. 1.

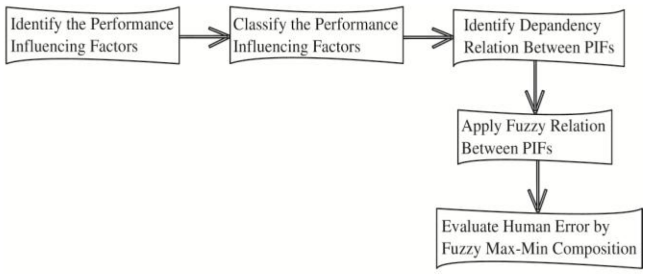

Fig. 1: Evaluation of human error through Fuzzy Relation

Power grid system (PGS) in [16] is considered as a case study for this work. The diagrammatic representation of human error casual frameworks is shown in Fig.2.

From fig.3, we observe that training quality, skill experience influences human error.

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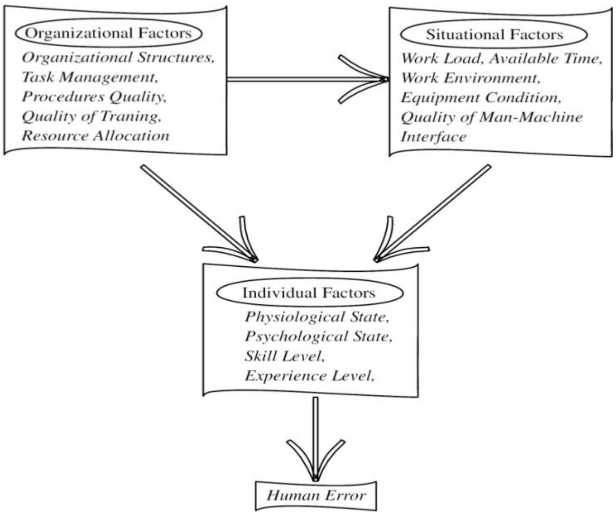

Fig. 2. PIF classification for HEP evaluation

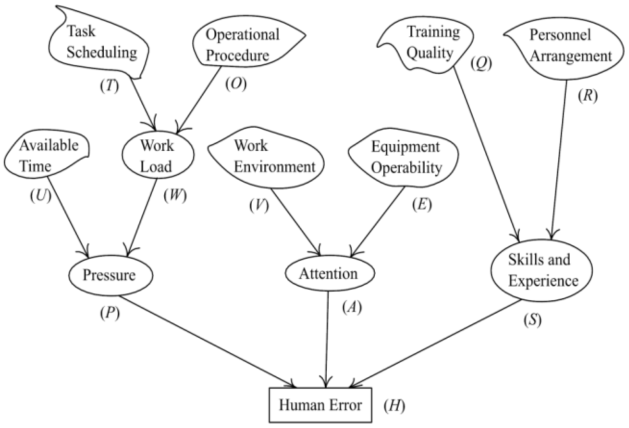

Fig. 3. Types of PIF of the PGS

Training quality is expressed in linguistic terms low, moderate and high; skill experience as low, moderate, high. PIFS of skill experience to identify human error is expressed as normal and error. The relations between these are expressed in Fig.4. To study this interdependency of training quality to identify human error using fuzzy composition is presented in the following calculation.

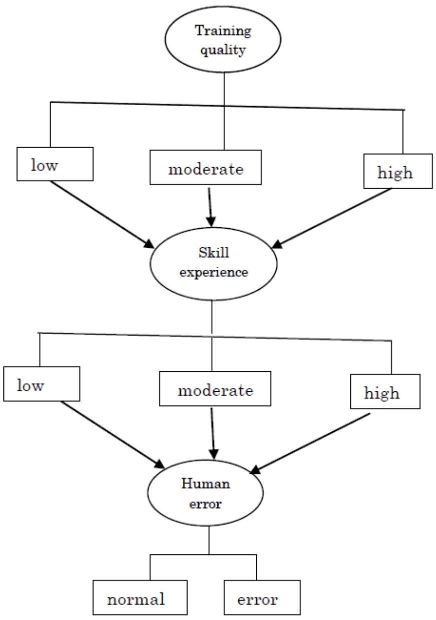

Fig. 4. Fuzzy composition

Calculations

1. If training quality is low and skill experience is low then a fuzzy composition exists from PIFs skill experience to human error.

$$\begin{matrix} & L & M & H \\ L & 0.9 & 0.09 & 0.01 \\ M & 0.7 & 0.2 & 0.1 \\ H & 0.2 & 0.6 & 0.2 \end{matrix} \circ \begin{matrix} & N & E \\ L & 0.3 & 0.7 \\ M & 0.5 & 0.5 \\ H & 0.7 & 0.3 \end{matrix} = \begin{matrix} & N & E \\ L & 0.3 & 0.7 \\ M & 0.3 & 0.7 \\ H & 0.5 & 0.5 \end{matrix}$$

2. If training quality is low and skill experience is moderate then a fuzzy composition exists from PIFs skill experience to human error.

$$\begin{matrix} & L & M & H \\ L & 0.9 & 0.09 & 0.01 \\ M & 0.7 & 0.2 & 0.1 \\ H & 0.2 & 0.6 & 0.2 \end{matrix} \circ \begin{matrix} & N & E \\ L & 0.5 & 0.5 \\ M & 0.8 & 0.2 \\ H & 0.9 & 0.1 \end{matrix} = \begin{matrix} & N & E \\ L & 0.5 & 0.5 \\ M & 0.5 & 0.5 \\ H & 0.6 & 0.2 \end{matrix}$$

3. If training quality is low and skill experience is high then a fuzzy composition exists from PIFs skill experience to human error.

$$\begin{matrix} & L & M & H \\ L & 0.9 & 0.09 & 0.01 \\ M & 0.7 & 0.2 & 0.1 \\ H & 0.2 & 0.6 & 0.2 \end{matrix} \circ \begin{matrix} & N & E \\ L & 0.7 & 0.3 \\ M & 0.9 & 0.1 \\ H & 0.99 & 0.01 \end{matrix} = \begin{matrix} & N & E \\ L & 0.7 & 0.3 \\ M & 0.7 & 0.3 \\ H & 0.6 & 0.2 \end{matrix}$$

4. If training quality is moderate and skill experience is low then a fuzzy composition exists from PIFs skill experience to human error.

$$\begin{matrix} & L & M & H \\ L & 0.7 & 0.2 & 0.1 \\ M & 0.2 & 0.6 & 0.2 \\ H & 0.1 & 0.6 & 0.3 \end{matrix} \circ \begin{matrix} & N & E \\ L & 0.3 & 0.7 \\ M & 0.5 & 0.5 \\ H & 0.7 & 0.3 \end{matrix} = \begin{matrix} & N & E \\ L & 0.3 & 0.7 \\ M & 0.5 & 0.5 \\ H & 0.5 & 0.5 \end{matrix}$$

5. If training quality is moderate and skill experience is moderate then a fuzzy composition exists from PIFs skill experience to human error.

$$\begin{matrix} & L & M & H \\ L & 0.7 & 0.2 & 0.1 \\ M & 0.2 & 0.6 & 0.2 \\ H & 0.1 & 0.6 & 0.3 \end{matrix} \circ \begin{matrix} & N & E \\ L & 0.5 & 0.5 \\ M & 0.8 & 0.2 \\ H & 0.9 & 0.1 \end{matrix} = \begin{matrix} & N & E \\ L & 0.5 & 0.5 \\ M & 0.2 & 0.2 \\ H & 0.6 & 0.2 \end{matrix}$$

6. If training quality is moderate and skill experience is high then a fuzzy composition exists from PIFs skill experience to human error.

$$\begin{matrix} & L & M & H \\ L & 0.7 & 0.2 & 0.1 \\ M & 0.2 & 0.6 & 0.2 \\ H & 0.1 & 0.6 & 0.3 \end{matrix} \circ \begin{matrix} & N & E \\ L & 0.7 & 0.3 \\ M & 0.9 & 0.1 \\ H & 0.99 & 0.01 \end{matrix} = \begin{matrix} & N & E \\ L & 0.7 & 0.3 \\ M & 0.6 & 0.2 \\ H & 0.6 & 0.1 \end{matrix}$$

7. If training quality is high and skill experience is low then a fuzzy composition exists from PIFs skill experience to human error.

$$\begin{matrix} & L & M & H \\ L & 0.2 & 0.6 & 0.2 \\ M & 0.1 & 0.3 & 0.6 \\ H & 0.01 & 0.09 & 0.9 \end{matrix} \circ \begin{matrix} & N & E \\ L & 0.3 & 0.7 \\ M & 0.5 & 0.5 \\ H & 0.7 & 0.3 \end{matrix} = \begin{matrix} & N & E \\ L & 0.5 & 0.5 \\ M & 0.6 & 0.3 \\ H & 0.7 & 0.3 \end{matrix}$$

8. If training quality is high and skill experience is moderate then a fuzzy composition exists from PIFs skill experience to human error.

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$$\begin{array}{c} \\ L \\ M \\ H \end{array}\begin{array}{c} \begin{array}{ccc} L & M & H \end{array} \\ \begin{bmatrix} 0.2 & 0.6 & 0.2 \\ 0.1 & 0.3 & 0.6 \\ 0.01 & 0.09 & 0.9 \end{bmatrix} \end{array} \circ \begin{array}{c} \\ L \\ M \\ H \end{array}\begin{array}{c} \begin{array}{cc} N & E \end{array} \\ \begin{bmatrix} 0.5 & 0.5 \\ 0.8 & 0.2 \\ 0.9 & 0.1 \end{bmatrix} \end{array} = \begin{array}{c} \\ L \\ M \\ H \end{array}\begin{array}{c} \begin{array}{cc} N & E \end{array} \\ \begin{bmatrix} 0.6 & 0.2 \\ 0.6 & 0.2 \\ 0.9 & 0.1 \end{bmatrix} \end{array}$$

9. If training quality is high and skill experience is high then a fuzzy composition exists from PIFs skill experience to human error.

$$\begin{array}{c} \\ L \\ M \\ H \end{array}\begin{array}{c} \begin{array}{ccc} L & M & H \end{array} \\ \begin{bmatrix} 0.2 & 0.6 & 0.2 \\ 0.1 & 0.3 & 0.6 \\ 0.01 & 0.09 & 0.9 \end{bmatrix} \end{array} \circ \begin{array}{c} \\ L \\ M \\ H \end{array}\begin{array}{c} \begin{array}{cc} N & E \end{array} \\ \begin{bmatrix} 0.7 & 0.3 \\ 0.9 & 0.1 \\ 0.99 & 0.01 \end{bmatrix} \end{array} = \begin{array}{c} \\ L \\ M \\ H \end{array}\begin{array}{c} \begin{array}{cc} N & E \end{array} \\ \begin{bmatrix} 0.6 & 0.2 \\ 0.6 & 0.1 \\ 0.99 & 0.09 \end{bmatrix} \end{array}$$

From fuzzy relation 1 we observe, when training quality is low, skill experience is low the possibility of human error is (0.3, 0.7). The other relations can be interpreted in similar manner. The benefit of fuzzy relation used in this work is that, the max-min composition yields the values to incorporate and estimate the possibility of occurring of errors.

III. CONCLUSION

This paper deals with the application of fuzzy relation between training quality, skill experience and human error. The interrelations between these linguistic features can be discussed effectively using fuzzy relation. The proposed approach can be implemented to other similar systems for evaluation of human error occurrence.

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